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**A TEMPERED STEEL METEORITE.**

BY E. GOLDSMITH.

Among the many objects brought to Philadelphia by the Peary Expedition to Greenland in 1891 was a meteorite weighing about 267 pounds. It was found by Professor Angelo Heilprin near Godhaven, Disco Island. The mass is somewhat pear-shaped and irregularly pitted. When received at the Academy it appeared to be solid and devoid of cracks or any signs of disintegration. This condition soon changed. The mass increased in volume, cracked, and began falling to pieces, apparently remaining dry during these changes. No drops of moisture or chloride of iron could be detected.

The assumption that the crumbling was due to oxidation was based on the fact of the existence of a higher temperature and a greater quantity of ozone in our latitude than in that of Greenland.

Professor Heilprin presented to me for examination some of the pieces which had separated from the mass. They were dull and gave evidence of oxidation. A little hammering sufficed to separate the substance into granules and powder, the distinction between them being marked. The granules are hard, metallic and tough, whilst the powder is capable of reduction to any degree of fineness. The separation, however, was not perfect, as the granules retained some oxide and the black powder included some of the finely divided particles of the metal. An attempt to separate the metal from the oxide with a bar magnet was unsuccessful because the whole mass was practically magnetic.

A determination of the separated quantities revealed: Granules=73.8%, Powder=26.2%. Specific gravity of the granules=6.14; that of the powder=4.73.

A portion of the specimen was reserved for grinding and etching; the process involved considerable difficulty because of the extreme hardness of the mass. The rotating stone, driven by a belt, appeared to be soft and powerless to reduce the meteorite, but by adding sand to the wet stone I succeeded, after hours of patient labor, in producing a plane surface. Further grinding with coarse and fine corundum and polishing with rouge produced a surface on which the etching would reveal its terrestrial or celestial origin. A new three edged saw-file was blunted by the first contact with the mass and no filings could be secured. Upon passing a sharp edge of the mass over a

plate of soft iron it made an impression alike visible to the eye and sensible to the touch. These three physical proofs would seem to warrant calling the object a tempered steel meteorite.

How the metal became tempered can only be explained hypothetically. Meteorites, in their passage through the atmosphere, become red-hot and if they fall into a pool of water or a deposit of snow or ice they are quickly cooled. Should the chemical composition be such as to form steel, the mass, under such conditions, becomes hardened. On heating one of the granules to redness and allowing it to cool slowly, its softness under the file-test conclusively demonstrated that natural steel is similar to the artificial product. The sharp-edged steel tool of a planing machine would doubtless have been broken by contact with the hard mass while in motion.

The extreme hardness might be supposed to indicate the presence of diamonds, but that mineral is never found in any of these suspected meteorites. The Widmanstättian figures are small, as might be expected when we consider the quick cooling; only small crystals forming under such circumstances.

Upon magnifying the figures about twenty diameters, by reflected light, the rectangular figures of the cube forming at times rod-shaped elongations and also triangular outlines of the octahedron, sometimes with sharply defined cleavage lines, were observed together with very acute triangles, which may belong to the tetrahedron.

A second surface on the same specimen, nearly at right angles to the first, was ground with greater ease on a corundum wheel running at great speed in order to determine whether the crystallization could be recognized to better advantage, but without result, as the second surface was no better than the first. That the structure might be presented to better advantage, the polished, etched surface was magnified about three diameters and photographed. (Plate IX, fig. 1). The lines, although faint, are apparent and, generally, the angular outlines of crystal forms can be easily traced. The half tones in the picture are the portions of the surface eaten out by the nitric acid. The shining surfaces are the reflections of the nickel steel and the dark pits are the crude untouched material. Cleavage lines predominate throughout the whole surface. A few of the regular outlines were drawn and appear in figure 2. The most common outline appears in figure 4. The dark crystalline figure was etched out by the acid treatment, as was also the larger dark

spot with peculiar markings within. The straight lines which cross each other are cleavages and have, in all probability, a structural meaning. If we focus into the deep pits of the specimen, crystalline bodies appear, of which a few have been drawn, (figure 3). These solid crystals, sometimes show a pale yellow color and may be troilite; some, however, have a deep blue tint, similar to the thin coat of oxide produced on heating iron or steel much below redness.

The microscopic investigation, which could be made only by reflected light, revealed some additional points. The mass is so very cellular and the cells, if the term be allowed, so close together as to require magnifying power in studying them. The quasi cells are filled out with the other material, thus constituting the whole mass. It is not difficult to recognize the faint brass (or yellow) colored troilite and the jet-black magnetite, the latter sometimes filling cells having a distinct crystalline contour as shown in figure 4.

The nickel is probably not evenly divided through the whole of the metallic mass, as part of the metal is readily affected by the nitric acid, while the rest is not. The tempered steel meteorite is, therefore, not homogeneous but highly compound.

Results were obtained by the qualitative chemical analysis showing conclusively the distinct difference between the granules and the separated dark powder. The former contains a sulphuret, probably troilite; the latter contains no sulphuret but, instead, a sulphate.

Iron, nickel, sulphur, traces of carbon, chlorine, phosphorus and chromium were found; also a silicate in which were recognized lime and magnesia. Copper and cobalt were searched for, but in vain. This leads me to direct attention to the Disco Island terrestrial iron, in which, according to Professor A. E. Nordenskiöld and J. L. Smith, are found copper, cobalt, phosphorus and comparatively large quantities of carbon, differences too great to be overlooked in comparing analytical work.

Composition of the granules :

Iron	.	.	.	.	86.66 per cent.
Nickel	.	.	.	.	2.32 per cent.
Sulphur	.	.	.	.	0.19 per cent.
x Silicate	.	.	.	.	4.41 per cent.
Oxygen	.	.	.	.	6.42 per cent.

If the sulphur is combined with iron to form troilite and the oxygen to form magnetite we have :

Iron . . . . .	66.79 per cent.
Nickel . . . . .	2.32 per cent.
Troilite ( $\text{FeS}$ ) . . . . .	0.52 per cent.
Magnetite ( $\text{Fe}_3\text{O}_4$ ) . . . . .	25.96 per cent.
x Silicate . . . . .	4.41 per cent.

Composition of the separated magnetic powder :

Iron . . . . .	68.18 per cent.
Nickel . . . . .	0.31 per cent.
Sulphuric anhydrite . . . . .	1.75 per cent.
Water . . . . .	3.43 per cent.
x Silicate . . . . .	10.10 per cent.
Oxygen . . . . .	16.23 per cent.

According to well known theoretical affinities we may expect the mixture to be :

Iron . . . . .	25.58 per cent.
Nickel . . . . .	0.31 per cent.
Magnetite ( $\text{Fe}_3\text{O}_4$ ) . . . . .	56.30 per cent.
Magnetic sulphate ( $\text{Fe}_3\text{O}_4, 2\text{SO}_3$ ) . . . . .	4.28 per cent.
x Silicate . . . . .	10.10 per cent.
Water . . . . .	3.43 per cent.

As long as there is any troilite in the mass a further oxidation and disintegration may be expected. The cellular structure of this steel meteorite seems to permit of such a process continuously.

My statement regarding the magnetic sulphate of iron, is made because, first: the whole of the powder is magnetic, whilst the basic sulphate of iron is not; and, secondly: when I tried to compute it as basic ferric sulphate I invariably obtained a numerical result whose aggregate was 1.05% too high. When regarding it as magnetic ferric sulphate no such discrepancy occurred.

My thanks are due to Professor Angelo Heilprin for the opportunity of investigating the first tempered steel meteorite.

#### EXPLANATION OF PLATE IX.

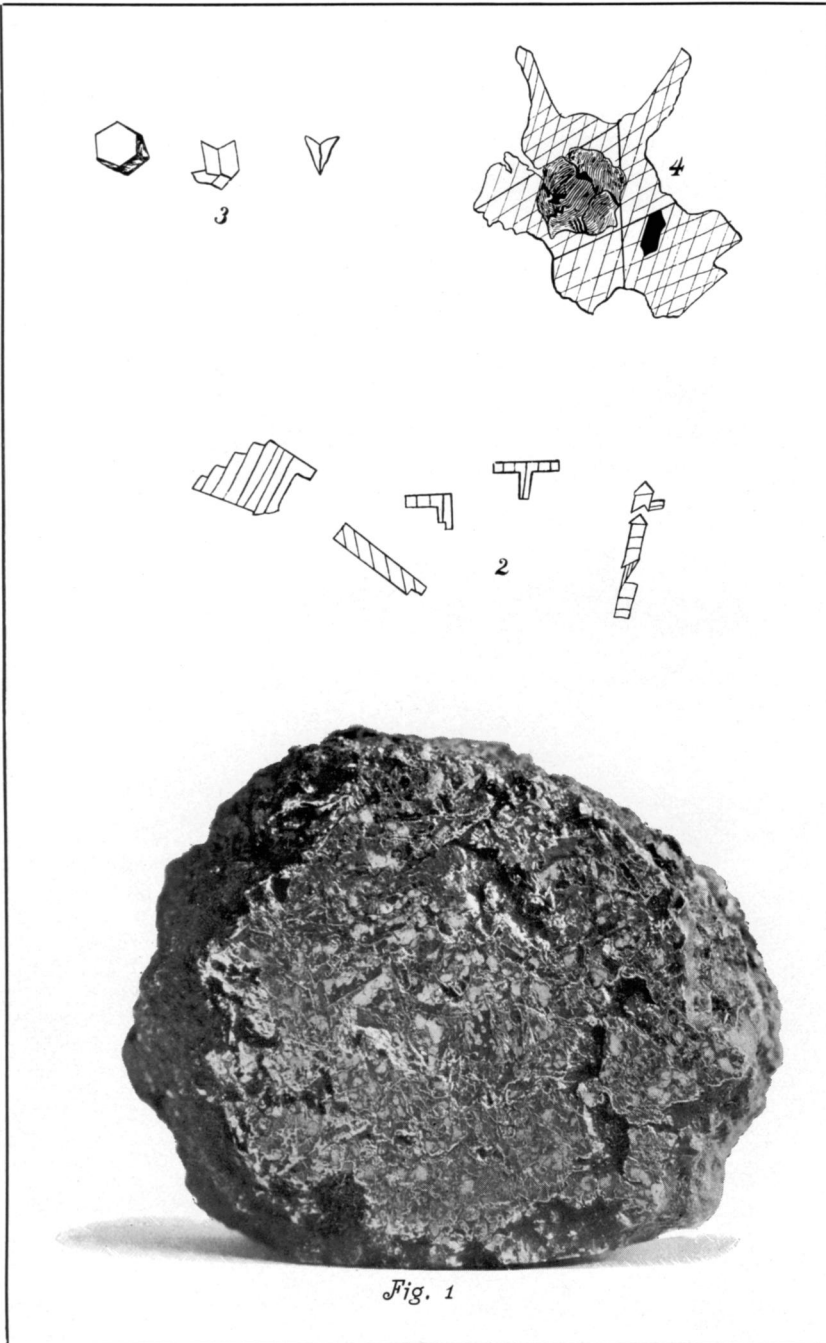
Fig. 1. Photographic projection of the polished and etched surface of the hard steel meteorite magnified about three diameters.

Fig. 2. Cubic and octahedral forms.

Fig. 3. Solid crystal forms as seen in the pits of the specimen.

Fig. 4. One of the many irregular outlined forms; the crossed lines represent the cleavages.

Figs. 2, 3 and 4 are magnified about twenty diameters.



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GOLDSMITH, TEMPERED STEEL METEORITE.